

## Specification

## ILLUMINATION CONTROL CIRCUIT

## Technical Field

[0001]

5           The present invention relates to an illumination control circuit which controls so-called brightness such as an illuminance and a light intensity of an illuminating lamp, a light emitting lamp, and a light emission element or the like.

## Technical Background

10   [0002]

          Japanese Unexamined Patent Application Publication No. Hei 11-233276 has disclosed an illumination control circuit (an illumination adjustment circuit) which drives an illuminating lamp for illuminating car audio device and adjusts its illuminance.

15   [0003]

          As shown in Fig. 1 of the above-mentioned patent document, the illumination adjustment circuit comprises a resistor (R1) and a zener diode (D1) connected in series with a power supply (Vcc), a switching transistor (Q2) which carries out a switching operation  
20   in accordance with a PWM signal (P), a filter circuit formed of resistors (R1, R2) and a capacitor (C1), a driving transistor (Q1) serving as a driving element for supplying a driving electric power from the power supply (Vcc) to an illuminating lamp (FL).

[0004]

25           In the illumination adjustment circuit having the above-described structure, the switching transistor (Q2) switches a constant voltage (V2) generated in the zener diode (D1) in response

to the PWM signal (P), while a switching output is smoothened by the filter circuit, thereby generating a DC voltage (VB) and determining a potential at the base of the driving transistor (Q1).  
[0005]

5           In this way, once a pulse width (W) of the PWM signal (P) is adjusted, it is possible to adjust a potential at the base of the driving transistor (Q1) and a driving electric power to be supplied to an illuminating lamp (FL), thus making it possible to adjust an illuminance of the illuminating lamp (FL).

10   [0006]

          Further, if the pulse width (W) of the PWM signal (P) is maintained at a predetermined width, the potential at the base of the driving transistor (Q1) may be maintained at a constant level by virtue of the DC voltage (VB), so that it is possible to maintain  
15   an illuminating lamp (FL) at a constant illuminance.  
[0007]

          Patent Document 1: Japanese Unexamined Patent Application Publication No. Hei 11-233276.

Disclosure of the Invention

20   Problem(s) to be Solved by the Invention  
[0008]

          In the above-described conventional illumination adjustment circuit, the constant voltage (V2) generated in the zener diode (D1) is used as a reference voltage, and such a constant voltage  
25   (V2) is switched and smoothened so as to generate a DC voltage (VB) for adjusting a potential at the base of the driving transistor (Q1). As a result, it becomes possible to perform an adjustment

on the illuminating lamp (FL) to ensure a constant illuminance, without being influenced by a voltage fluctuation of the power supply (Vcc).

[0009]

5           However, when a fluctuation occurs in the power supply (Vcc) and a voltage level rises up, since the potential at the base of the driving transistor (Q1) is maintained at a constant level by virtue of the DC voltage (VB), a voltage between the collector and the base of the driving transistor (Q1) will also rise, resulting  
10 in a problem that the transistor's collector loss is large.

[0010]

          In particular, when driving/controlling an illuminating lamp (FL) which requires a large electric power consumption, once a voltage level of a power supply (Vcc) rises up, a load on the driving  
15 transistor (Q1) will increase, thus causing a rapid increase in the collector loss of the driving transistor (Q1), or a deterioration in the characteristic of the driving transistor (Q1), which is caused possibly due to a heat generation, hence bringing about a problem of causing a wound or the like.

20 [0011]

          The present invention has been accomplished in view of the above-discussed conventional problem and it is an object of the invention to provide an illumination control circuit having a driving element for driving an illuminating lamp, a light emitting lamp,  
25 a light emission element or the like, thereby ensuring an improved illumination control circuit capable of reducing a load on the driving element, even if there has been a fluctuation or the like on the

power source voltage.

[0012]

Another object of the invention is to provide an improved illumination control circuit capable of stabilizing a brightness  
5 such as an illuminance and a light intensity of an illuminating lamp, a light emitting lamp, and a light emission element or the like, even if there has been a fluctuation or the like on the power source voltage.

Means for Solving the Problem

10 [0013]

An invention recited in claim 1 is an illumination control circuit for driving and controlling a light emission element, said circuit comprising: detecting means for detecting a power source voltage of a power supply and outputting a detection voltage in  
15 response to a change of the power source voltage; and a driving element and compensation means connected in series with the light emission element and the power supply, said driving element being provided for driving said light emission element and said compensation means being provided for generating a compensation  
20 voltage following the detection voltage. In particular, said compensation means, by generating a compensation voltage following the detection voltage, inhibits a change of a driving voltage applied between two ends of said light emission element and said driving element, with respect to a change in the power source voltage of  
25 said power supply.

[0014]

An invention recited in claim 7 is an illumination control

circuit for driving and controlling a light emission element, said circuit comprising: a driving element connected in series with the light emission element and a power supply, said driving element being provided for driving said light emission element; compensation  
5 means for supplying a control signal to the driving element; and detecting means for detecting a power source voltage of the power supply, outputting a detection voltage in response to a change of said power source voltage, and for inhibiting a level change of the control signal by adjusting the compensation means using the  
10 detection voltage.

#### Brief Description of the Drawings

[0015]

Fig. 1 is a circuit diagram showing a structure of an illumination control circuit according to a first embodiment of  
15 the present invention.

Fig. 2 provides characteristic graphs explaining basic properties of the illumination control circuit shown in Fig. 1.

Fig. 3 is a circuit diagram showing a structure of an illumination control circuit according to a second embodiment.

20 Fig. 4 is a circuit diagram showing a structure of an illumination control circuit according to a first example.

Fig. 5 is a circuit diagram showing a structure of an illumination control circuit according to a second example.

#### Best Mode of Carrying Out the Invention

25 [0016]

Next, description will be given to explain two embodiments of the illumination control circuit of the present invention, with

reference to Figs. 1 to 3.

[0017]

[Embodiment 1]

Fig. 1 is a circuit diagram showing a structure of an  
5 illumination control circuit according to a first embodiment of  
the present invention.

As shown in Fig. 1, the illumination control circuit 1 comprises  
a control signal source 2, a switching element 3 serving as a control  
element, a smoothing unit 4, a driving element 5, a reference unit  
10 6, a detecting unit 7, and a compensating unit 8. When the  
illumination control circuit 1 is connected to a power source PWR  
such as a vehicle battery mounted in a vehicle, the illumination  
control circuit 1 will operate to control the illuminance or the  
light intensity of an illuminating lamp, a light emitting lamp and  
15 a light emission element FL which all receive an electric power  
supplied from the power source PWR and thus emit light.

[0018]

In the following, for an easy description, an illuminating  
lamp, a light emitting lamp and a light emission element will all  
20 be simply referred to as "light emission element".

[0019]

The control signal source 2 is formed of an oscillating circuit  
outputting PWM signal S1, and can variably adjust a pulse width  
(a pulse width when the signal becomes logically "H") of the PWM  
25 signal S1 by virtue of an external operation. In other words, the  
control signal source 2 can variably adjust the duty of the PWM  
signal S1 by an external operation.

[0020]

The switching element 3 performs a switching operation in accordance with the PWM signal S1 and outputs a square wave switching signal S2 logically inverted with respect to the PWM signal S1.

5 [0021]

The smoothing unit 4 is formed of a low pass filter or the like, and smoothens the switching signal S2, thereby outputting a DC voltage V4 as a control signal.

[0022]

10 The driving element 5 is connected between the light emission element FL and the compensation circuit 8, and sets a driving electric power which causes the light emission element FL to emit a light in accordance with the DC voltage V4.

[0023]

15 Here, in the present embodiment, a PNP transistor is used as the driving element 5, the DC voltage is applied to the base of the PNP transistor, the compensation unit 8 is connected to the collector of the PNP transistor, one input terminal of the light emission element FL is connected to the emitter of the PNP transistor,  
20 and the other input terminal of the light emission element FL is connected to the power supply PWR.

[0024]

Then, since a smaller pulse width W of the PWM signal S1 will cause a larger increase in the DC voltage V4, the driving element  
25 5 will reduce a driving electric power which causes the light emission element FL to emit a light. On the other hand, since a larger pulse width W of the PWM signal S1 will cause a larger decrease in the

DC voltage V4, the driving element 5 will increase a driving electric power which causes the light emission element FL to emit a light.  
[0025]

The reference unit 6 and the detecting unit 7 are connected  
5 in series between the minus side output terminal (-) and the plus side output terminal (+) of the power supply PWR. Here, the reference unit 6 is formed of an electric element or an electric circuit which generates a constant voltage Vz, such as a zener diode or a constant voltage circuit.

10 [0026]

The detecting unit 7 detects a differential voltage ( $V_{cc}-V_z$ ) between the constant voltage Vz and the power source voltage Vcc which is higher than the constant voltage Vz outputted from the power supply PWR, and generates a detection voltage V2 represented  
15 by the following equation (1) which is an equivalent to a multiplication product of the differential voltage ( $V_{cc}-V_z$ ) and a predetermined coefficient  $\alpha$ . Here, the coefficient  $\alpha$  is a positive constant value which is larger than 0 and smaller than 1.  
[0027]

20 
$$V2 = \alpha(V_{cc}-V_z) \dots (1)$$

For an easy description, if the minus side output terminal (-) of the power supply PWR is defined as ground (GND) terminal, a voltage V1 generated at a junction point between the reference unit 6 and the detecting unit 7 is a differential voltage ( $V_{cc}-V_z$ )  
25 which is a plus value with respect to (GND) terminal. Such differential voltage ( $V_{cc}-V_z$ ) is detected by the detecting unit 7, thereby generating a detection voltage V2 represented by the



above equation (1).

[0028]

The compensation unit 8 is formed of an active element or an active circuit such as a transistor or an amplifier, and generates a compensation voltage V3 following the detection voltage V2 by power-amplifying the detection voltage V2, thereby setting a potential at a junction point P between the driving element 5 and the compensation unit 8 by virtue of the compensation voltage V3.

[0029]

The compensation unit 8 is formed of the foregoing active element or active circuit in a manner such that an impedance when viewing the compensation unit 8 from the driving element 5 is lower than an impedance when viewing the driving element 5 from the compensation unit 8. As a result, it is possible to set a potential at a junction point P between the driving element 5 and the compensation unit 8 by virtue of the compensation voltage V3 having a lower impedance.

[0030]

Here, although the compensation unit 8 of the present embodiment is constructed to generate a compensation voltage V3 higher than the detection voltage V2 by carrying out a power amplification of the detection voltage V2, it is also possible to generate a compensation voltage V3 which is equal to or lower than the detection voltage V2. Namely, the compensation unit 8 outputs a compensation voltage V3 which rises when the detection voltage V2 rises and drops when the detection voltage V2 drops.

[0031]

Next, description will be given to explain basic characteristics and operation of the illumination control circuit 1, with reference to Fig. 1 and Fig. 2.

[0032]

5 <Basic characteristics of the illumination control circuit 1>

At first, description will be given to explain basic characteristics of the illumination control circuit 1 with reference to Fig. 2.

[0033]

10 Fig. 2 shows characteristics which occur when a power source voltage  $V_{cc}$  gradually rises from 0 (Volt), thereby explaining basic characteristics of the illumination control circuit 1. Fig. 2(a) is a characteristic graph showing changes in a voltage  $V_z$  generated between both ends of the reference unit 6, a voltage  $V_1$  which is  
15 a differential voltage ( $V_{cc}-V_z$ ) generated between both ends of the detecting unit 7, a detection voltage  $V_2$  outputted from the detecting unit 7, a compensation voltage  $V_3$  generated between both ends of the compensation unit 8, a driving voltage  $V_x$  generated between the light emission element FL and the driving element 5. Fig. 2(b) and Fig. 2(c) are characteristic graphs showing changes of the driving  
20 voltage  $V_x$  with respect to the power source voltage  $V_{cc}$ .

[0034]

As shown in Fig. 2(a), when the power source voltage  $V_{cc}$  increases every predetermined voltage with the passing of time,  
25 since the reference unit 6 formed of a zener diode or the like will not operate within a range in which the power source voltage  $V_{cc}$  has not reached a predetermined voltage (such as a zener voltage)

Vzg, there will not be a constant voltage Vz. On the other hand, if the power source voltage Vcc becomes equal to or higher than a predetermined voltage Vzg, there will be a constant voltage Vz which is almost equal to the voltage Vzg.

5 [0035]

Since the voltage V1 is a differential voltage ( $V_{cc}-V_z$ ) between the power source voltage Vcc and the constant voltage Vz, such a differential voltage will change following a change of the power source voltage Vcc within a range in which the power source voltage Vcc is equal to or higher than the voltage Vzg.

[0036]

The detection voltage V2 changes following the voltage V1 within a range in which the power source voltage Vcc is equal to or higher than the voltage Vzg. Similarly, the compensation voltage V3 also changes following the voltage V1 and the detection voltage V2. On the other hand, since the detection voltage V2 changes in accordance with the above-mentioned equation (1), it changes at a voltage changing rate which is slower than the voltage changing rate of the voltage V1. Further, the compensation voltage V3 also changes at a slower voltage changing rate following the detection voltage V2.

[0037]

Since the driving voltage Vx is equal to a differential voltage ( $V_{cc}-V_3$ ) between the power source voltage Vcc and the compensation voltage V3, such a driving voltage Vx will change following a change of the power source voltage Vcc.

[0038]

Namely, the driving voltage  $V_x$  changes following the power source voltage  $V_{cc}$  within a range in which the power source voltage  $V_{cc}$  is equal to or higher than the voltage  $V_{zg}$ . On the other hand, since an increase of the power source voltage  $V_{cc}$  will soon cause  
5 an increase of the compensation voltage  $V_3$ , the driving voltage  $V_x$  will change at a voltage changing rate which is smaller than a voltage changing rate of the power source voltage  $V_{cc}$ .

[0039]

Furthermore, it is understood from the above equation (1) that  
10 when the coefficient  $\alpha$  is variably adjusted, the voltage changing rate of the detection voltage  $V_2$  will also change in response to a change of the power source voltage  $V_{cc}$ . As a result, as shown in Fig. 2(c), there will be a change in the voltage changing rate of the driving voltage  $V_x$  which changes following the power source  
15 voltage  $V_{cc}$ .

[0040]

Further, the illumination control circuit 1 is connected with the power supply PWR which outputs the power source voltage  $V_{cc}$  having a higher voltage (for example, voltage  $V_{ccg}$ ) than the constant  
20 voltage  $V_z$  (namely, voltage  $V_{zg}$ ) generated in the reference unit 6.

[0041]

Next, description will be given to explain an operation of the illumination control circuit 1 having the above-described basic  
25 characteristics.

[0042]

<Operation of the illumination control circuit 1 when the power

source voltage  $V_{cc}$  is stable>

In a case where the illumination control circuit 1 is connected with the power supply PWR which outputs the power source voltage  $V_{cc}$  and the power source voltage  $V_{cc}$  is stable, once the coefficient  $\alpha$  of the above equation (1) is set at a predetermined value, the driving voltage  $V_x$  applied between two ends of the light emission element FL and the driving element 5 will be held at the voltage  $V_{xs}$  corresponding to the voltage  $V_{ccg}$  shown in Fig. 2(b).

[0043]

With a driving voltage  $V_x$  kept at a constant voltage, a user can perform an external operation on the control signal source 2. Once there is an output of PWM signal S1 having an appropriate pulse width W, a switching element 3 will generate a switching signal S2 in accordance with the PWM signal S1, while the smoothing unit 4 will smoothen the switching signal S2, thereby generating a DC voltage  $V_4$  proportional to the pulse width W of the PWM signal S1. Then, the driving element 5 sets a predetermined driving electric power in response to the DC voltage  $V_4$ , thereby adjusting the illuminance or the light intensity (so-called brightness) of the light emission element FL to a brightness corresponding to the pulse width W of the PWM signal S1.

[0044]

Therefore, if a user or the like performs an external operation on the control signal source 2 to keep the pulse width W of the PWM signal S1 at an appropriate pulse width, it is possible to adjust the illuminance or the light intensity (so-called brightness) of the light emission element FL to a desired brightness.

[0045]

Furthermore, once a user or the like performs an external operation on the control signal source 2 to keep the pulse width W of the PWM signal S1 at an appropriate pulse width, the DC voltage V4 will remain at a voltage in response to the pulse width W, thereby making it possible to maintain the light emission element FL at an illuminance or light intensity (so-called brightness) desired by a user or the like.

[0046]

10 In addition, according to the illumination control circuit 1, when the power source voltage Vcc is stabilized at a fixed voltage, since the driving voltage Vx is also maintained at a predetermined voltage (i.e., voltage Vxs), it is possible to maintain a user's desired brightness without exerting a large load on the driving  
15 element 5, and without changing the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0047]

<Operation of the illumination control circuit 1 when there has been a fluctuation or the like in the power source voltage Vcc>

20 Next, description will be given to explain an operation where the power source voltage Vcc has changed. For example, in a case where the power supply PWR is a vehicle battery mounted in a vehicle, since the power supply PWR is electrically charged by an electricity generator, there will be a fluctuation such as an increase in the  
25 power source voltage Vcc.

[0048]

In a case where the power source voltage Vcc goes up due to

a fluctuation or the like, since the constant voltage  $V_z$  of the reference unit 6 remains at the foregoing voltage  $V_{zg}$ , it is understood from equation (2) that the detection voltage  $V_2$  and the compensation voltage  $V_3$  will rise with the power source voltage  $V_{cc}$ , and the driving voltage  $V_x$  will also rise following the power source voltage  $V_{cc}$ . On the other hand, as shown in Fig. 2(b), the driving voltage  $V_x$  will also change at a relatively small voltage changing rate as compared with the power source voltage  $V_{cc}$ , with the voltage  $V_{xs}$  serving as a reference.

10 [0049]

For this reason, even if the power source voltage  $V_{cc}$  goes up, there would be no large load on the driving element 5, and it is possible to effect a light emission without changing the illuminance or the light intensity (so-called brightness) of the light emission element FL.

15

[0050]

Then, when a user or the like performs an external operation on the control signal source 2 to adjust the pulse width  $W$  of the PWM signal  $S_1$ , the DC voltage  $V_4$  in response to the PWM signal  $S_1$  will be applied to the driving element 5 which is biased by the driving voltage  $V_x$  having a small voltage change. As a result, the driving element 5 can cause the light emission element FL to emit a light at an illuminance or light intensity (so-called brightness) adjusted by a user or the like, thereby making it possible to effect a user's desired light emission without bringing about any irregularity to the brightness.

25

[0051]

Namely, as shown in Fig. 2(b), when the power source voltage  $V_{cc}$  goes up, since the driving voltage  $V_x$  will change a little, more exactly, since there will be a change in the illuminance or the light intensity (so-called brightness) of the light emission element FL, it is possible to ensure the following effect. Namely, by adjusting in advance the coefficient  $\alpha$  of the detecting unit 7, it is possible to reduce a voltage changing rate with respect to the power source voltage  $V_{cc}$  of the driving voltage  $V_x$ . In this way, it is possible to inhibit a change of the driving voltage  $V_x$  in a manner such that the illuminance or the light intensity (so-called brightness) of the light emission element FL will change only within a range which will not be felt by man's eyes. Therefore, using the illumination control circuit 1 makes it possible to effect a desired light emission without bringing about any irregularity to the illuminance or the light intensity (so-called brightness) of the light emission element FL, even if there has been an increase in the power source voltage  $V_{cc}$ .

[0052]

Moreover, even in a case where the power source voltage  $V_{cc}$  drops from the voltage  $V_{ccg}$  shown in Fig. 2(b), it is still possible to ensure the following effect, provided that the constant voltage  $V_z$  of the reference unit 6 is within a range of voltage  $V_{zg}$ . Namely, since a voltage change of the driving voltage  $V_x$  is small, it is possible to use the driving element 5 to effect a desired light emission without bringing about any irregularity to the illuminance or the light intensity (so-called brightness) of the light emission element FL.



[0053]

For example, when the rated voltage  $V_{cc}$  of the power source voltage  $V_{cc}$  is 12 (Volt) and the constant voltage  $V_z$  generated by the reference unit 6 is 5.3 (Volt), if the power source voltage  $V_{cc}$  has dropped within a range from 12 (Volt) to 5.3 (Volt), since the voltage change of the driving voltage  $V_x$  is small, it is possible to use the driving element 5 to effect a desired light emission without bringing about any irregularity to the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0054]

As described above, according to the illumination control circuit 1 of the present embodiment, the light emission element FL, the driving element 5, and the compensation unit 8 are connected in series with respect to the power source voltage  $V_{cc}$ . The detecting unit 7 detects a voltage change of the power source voltage  $V_{cc}$ , the compensation unit 8 generates a compensation voltage  $V_3$  which follows a change of the power source voltage  $V_{cc}$ , so that it is possible to reduce a change in a voltage between two ends of the light emission element FL and the driving element 5, i.e., the driving voltage  $V_x$ , even if there has been a change in the power source voltage  $V_{cc}$ . Further, it is possible to reduce a load on the driving element 5. Moreover, since it is possible to reduce a change of the driving voltage  $V_x$ , it is possible to stabilize the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0055]

Furthermore, the reference unit 6 and the detecting unit 7 are provided with respect to the power source voltage  $V_{cc}$ , the detecting unit 7 detects a change in the power source voltage  $V_{cc}$  in accordance with the differential voltage ( $V_{cc}-V_z$ ) between the power source voltage  $V_{cc}$  and the constant voltage  $V_z$  generated in the reference unit 6, while the compensation unit 8 generates the compensation voltage  $V_3$  in accordance with the detection result (detection voltage)  $V_2$ , so that it is possible to reduce a change in the driving voltage  $V_x$  between two ends of the light emission element FL and the driving element 5, even if the power source voltage  $V_{cc}$  has become higher than the so-called rated voltage  $V_{ccg}$ . Besides, it is possible to reduce a load on the driving element 5, and to stabilize the illuminance or the light intensity (so-called brightness) of the light emission element FL. In addition, even when the power source voltage  $V_{cc}$  becomes lower than the so-called rated voltage  $V_{ccg}$ , within a range from the rated voltage  $V_{ccg}$  to the constant voltage  $V_z$  it is possible to reduce a change in the driving voltage  $V_x$  between two ends of the light emission element FL and the driving element 5, thereby alleviating a load on the driving element 5 and stabilizing the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0056]

Furthermore, since the detection voltage  $V_2$  outputted from the detecting unit 7 with respect to a change of the power source voltage  $V_{cc}$  can be variably adjusted by virtue of the coefficient  $\alpha$  of the above equation (1), it is possible to adjust the driving voltage  $V_x$  with respect to the power source voltage  $V_{cc}$ . For example,

it is possible to perform an adjustment to inhibit a change of the driving voltage  $V_x$ , corresponding to an actual changing characteristic of the power source voltage  $V_{cc}$ .

[0057]

5           For this reason, even in a case where various different power supplies PWR having different power source voltages  $V_{cc}$  and different changes are used to control the illuminance or the light intensity of the light emission element FL, it is possible to obtain an advantage of adjusting a change of the driving voltage  $V_x$  in accordance with  
10 the characteristic of the power supply PWR.

[0058]

[Embodiment 2]

Next, description will be given to explain an illumination control circuit formed according to a second embodiment of the present  
15 invention, with reference to Fig. 3. Here, Fig. 3 is a circuit diagram showing a structure of the illumination control circuit 1 of the present embodiment, with the elements identical or equal to those in Fig. 1 being represented by the same reference numerals.

[0059]

20           As shown in Fig. 3, the illumination control circuit 1 comprises a control signal source 2, a switching element 3 serving as a control unit, a smoothing unit 4, a driving element 5, a reference unit 6, a detecting unit 7, and a compensation unit 10.

[0060]

25           Similar to the first embodiment shown in Fig. 1, the control signal source 2 is formed of an oscillating circuit which outputs the PWM signal S1, and capable of variably adjusting the pulse width

W of the PWM signal S1 by virtue of an external operation inputted thereto.

[0061]

The switching element 3 performs a switching operation in accordance with the PWM signal S1, and outputs a square wave switching signal S2.

[0062]

The smoothing unit 4 is formed of a low pass filter or the like and smoothens the switching signal S2, thereby generating a DC voltage V4 as a control signal in response to the above-mentioned pulse width W. In fact, a smaller pulse width W of the PWM signal S1 will induce a larger increase in the DC voltage V4 and a larger pulse width W of the PWM signal S1 will cause a larger decrease in the DC voltage V4.

15 [0063]

The compensation unit 10 sets up the control current Id for operating the driving element 5 in accordance with the DC voltage V4.

[0064]

20 The driving element 5 and the light emission element FL are connected in series between the plus side output terminal (+) and the minus side output terminal (-) of the power supply PWR, while the driving element 5 operates to set a driving electric power which causes the light emission element FL to emit a light in accordance with the control current Id.

25 [0065]

Here, in the present embodiment, the driving element 5 is formed

of a PNP transistor, the emitter of the PNP transistor is connected to the plus side output terminal (+) of the power supply PWR, the collector thereof is connected to the light emission element FL, while the base of the transistor is connected to the compensation unit 10 and controlled by the control current Id.

[0066]

The compensation unit 10 is provided such that once the DC voltage V4 increases, the compensation unit 10 will increase the control current Id, so as to increase the base current (in other words, a suction current) of the PNP transistor. On the other hand, once the DC voltage V4 decreases, the compensation unit 10 will reduce the control current Id, thereby reducing the base current of the PNP transistor. In this way, the driving element (PNP transistor) 5 operates in a manner such that once DC voltage V4 increases, the driving element will increase the driving electric power which causes the light emission element FL to emit a light. On the other hand, once the DC voltage V4 decreases, the driving element 5 will reduce the driving electric power which causes the light emission element FL to emit a light.

[0067]

The reference unit 6 and the detecting unit 7 are connected in series between the plus side output terminal (+) and the minus side output terminal (-) of the power supply PWR. The reference unit 6 is formed of an electronic element or an electronic circuitry which generates the constant voltage Vz, such as a zener diode and a constant voltage circuit, and generates a constant voltage Vz which is smaller than the power source voltage Vcc.

[0068]

The detecting unit 7 detects a differential voltage ( $V_{cc}-V_z$ ) between the power source voltage  $V_{cc}$  and the constant voltage  $V_z$  of the power supply PWR, thereby generating a detection voltage  $V_2$  expressed in the following equation (2); between the junction point between the detecting unit 7 and the switching element 3 on one hand and the minus side output terminal (-) of the power supply PWR on the other. Here, the coefficient  $\beta$  is a positive constant value which is larger than 0 and smaller than 1.

10 [0069]

$$V_2 = \beta \times (V_{cc}-V_z) + V_z \quad \dots (2)$$

Namely, the detecting unit 7 generates, as the detection voltage  $V_2$ , a voltage formed by adding the constant voltage  $V_z$  to a voltage which is  $\beta \times (V_{cc}-V_z)$  formed by multiplying the differential voltage ( $V_{cc}-V_z$ ) with the coefficient  $\beta$ . Then, the detecting unit 7 sets an emitter potential of the switching element 3 consisting of PNP transistor by virtue of the detection voltage  $V_2$ .

[0070]

Next, description will be given to explain an operation of the illumination control circuit 1 having the above-described structure.

[0071]

At first, description will be given to explain an operation of the illumination control circuit 1 under a constant condition without any change in the power source voltage  $V_{cc}$ .

[0072]

The reference unit 6 generates the constant voltage  $V_z$ , and

the detecting unit 7 sets an emitter potential of the switching element 3 consisting of PNP transistor, in accordance with the foregoing differential voltage ( $V_{cc}-V_z$ ) and the detection voltage  $V_2$ . Furthermore, under a constant condition without any change in the power source voltage  $V_{cc}$ , the detection voltage  $V_2$  remains at a constant voltage, and the emitter potential of the switching element 3 consisting of PNP transistor is also held at a constant voltage by virtue of the detection voltage  $V_2$ .

[0073]

Under the above-described condition, a user or the like performs an external operation on the control signal source 2. Once there is an output of the PWM signal  $S_1$  having an appropriate pulse width  $W$ , the switching element 3 will generate the switching signal  $S_2$  according to the PWM signal  $S_1$ , while the smoothing unit 4 will generate DC voltage  $V_4$  in accordance with the switching signal  $S_2$ .

[0074]

The driving element 5 sets a predetermined driving electric power in response to the DC voltage  $V_4$ , and adjusts the illuminance or the light intensity (so-called brightness) of the light emission element FL to a brightness in response to the pulse width  $W$  of the PWM signal  $S_1$ .

[0075]

Therefore, when a user or the like performs an external operation on the control signal source 2 to adjust the pulse width  $W$  of the PWM signal  $S_1$  in order to lower the DC voltage  $V_4$ , the power amplification rate of the driving element 5 will decrease, making it possible to reduce the illuminance or the light intensity

(so-called brightness) of the light emission element FL. On the other hand, upon adjusting the pulse width W of the PWM signal S1 in order to increase the DC voltage V4, the power amplification rate of the driving element 5 will increase, making it possible to increase the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0076]

Moreover, when a user or the like performs an external operation on the control signal source 2 to maintain the pulse width W of the PWM signal S1 at an appropriate pulse width, the DC voltage V4 will remain at a voltage in response to the foregoing pulse width, thereby rendering it possible to maintain the illuminance or the light intensity (so-called brightness) of the light emission element FL at a desired brightness.

[0077]

Next, description will be given to explain an operation of the illumination control circuit 1 in a case where the power source voltage Vcc has changed due to a voltage fluctuation.

[0078]

When the power source voltage Vcc of the power supply PWR goes up due to a voltage fluctuation or the like, the reference unit 6 will generate a constant voltage Vz irrespective of a change in the power source voltage Vcc. Further, according to the above equation (2), the detecting unit 7 generates a detection voltage V2 from the foregoing differential voltage ( $V_{cc} - V_z$ ).

[0079]

Here, since the constant voltage Vz does not change even if



there is a fluctuation in the power source voltage  $V_{cc}$ , the differential voltage ( $V_{cc}-V_z$ ) will rise with an increase in the power source voltage  $V_{cc}$ , while the detecting unit 7 detects an increase in the differential voltage ( $V_i-V_z$ ) and outputs a detection  
5 voltage  $V_2$  which goes up due to an increase in the power source voltage  $V_{cc}$ .

[0080]

In this way, if the detection voltage  $V_2$  rises with the rise of the power source voltage  $V_{cc}$ , a voltage between the emitter and  
10 the base of the switching element 3 consisting of PNP transistor will become large, and the voltage amplification factor of the switching element 3 will also become large.

[0081]

Then, once the voltage amplification factor of the switching  
15 element 3 becomes large, the amplitude of the switching signal  $S_2$  will also become large, the voltage level of the DC voltage  $V_4$  outputted from the smoothing unit 4 will go up, thereby increasing a driving electric power supplied to the light emission element FL by the driving element 5 consisting of the PNP transistor.

20 [0082]

Here, an important point which should be noted is that when the power source voltage  $V_{cc}$  goes up due to a fluctuation or the like, the detection voltage  $V_2$  will rise depending on the coefficient  $\beta$  of the above equation (2), so that the voltage amplification factor  
25 of the detection voltage  $V_2$  becomes gentle (small) as compared with the voltage changing rate of the power source voltage  $V_{cc}$ . For this reason, although the voltage between the emitter and the base of

the switching element 3 becomes large with the rise of the power source voltage  $V_{cc}$ , such a voltage will also become large at a voltage changing rate which is smaller than the voltage changing rate of the power source voltage  $V_{cc}$ , under a constitution in which the voltage amplification rate of the switching element 3 has been inhibited.

[0083]

Therefore, the amplitude of the switching signal  $S_2$  becomes large in accordance the voltage amplification factor of the controlled switching element 3. The voltage level of the DC voltage  $V_4$  outputted from the smoothing unit 4 goes up also in accordance with the voltage amplification factor of the controlled switching element 3. Further, the power amplification of the driving element consisting of PNP transistor will also increase in accordance with the voltage amplification factor of the controlled switching element 3, with no significant change in the driving electric power supplied to the light emission element FL. For this reason, there would be no significant change in the illuminance or the light intensity (so-called brightness) of the light emission element FL, with any change remaining within a range in which there is not any irregularity in the brightness.

[0084]

Moreover, even in a case where the power source voltage  $V_{cc}$  has dropped, if the power source voltage  $V_{cc}$  drops from the rated voltage to a range in which the reference unit 6 generates the constant voltage  $V_z$ , it is still possible to ensure a bias voltage between the emitter and the base of the switching element 3 consisting of

PNP transistor, by virtue of the detection voltage  $V_2$ . Further, since the detection voltage  $V_2$  drops depending on the coefficient  $\beta$  of the above equation (2), the voltage amplification factor of the detection voltage  $V_2$  will become gentle (small) as compared with the voltage changing rate of the power source voltage  $V_{cc}$ .  
[0085]

For this reason, although a voltage between the emitter and the base of the switching element 3 becomes small with the dropping of the power source voltage  $V_{cc}$ , such a voltage will decrease at a voltage changing rate smaller than the voltage changing rate of the power source voltage  $V_{cc}$ , the voltage amplification factor of the switching element 3 will drop in an inhibited state, the electric power amplification factor of the driving element 5 consisting of PNP transistor will also decrease in response to the voltage amplification factor of the controlled switching element 3, without any considerable change in the driving electric power being supplied to the light emission element FL. Accordingly, even when the power source voltage  $V_{cc}$  has decreased, there would be no considerable change in the illuminance or the light intensity (so-called brightness) of the light emission element FL, with any change remaining within a range in which there is not any irregularity in the brightness.

[0086]

As explained above, according to the illumination control circuit 1 of the present embodiment, even when there has been a fluctuation or the like in the power source voltage  $V_{cc}$ , it is still possible to use the reference unit 6 and the detecting unit 7 to

adjust the DC voltage V4 and the control current Id in a manner such that the load on the driving element 5 will not become large. Further, it is also possible to stabilize the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0087]

Moreover, since a change in the power source voltage Vcc will soon cause a change in the detection voltage V2, the voltage amplification factor of the switching element 3 will also change and DC voltage V4 will also change. As a result, although there will be a change in the illuminance or the light intensity (so-called brightness) of the light emission element FL, if the coefficient  $\beta$  of the detecting unit 7 is adjusted in advance, it is possible to reduce a voltage changing rate with respect to the power source voltage Vcc of the detection voltage V2, making it possible to reduce a change in the DC voltage V4, in a manner such that the illuminance or the light intensity (so-called brightness) of the light emission element FL changes only within a range which will not be felt by man's eyes. Furthermore, since it is possible to reduce a fluctuation of the DC voltage V4, it is possible to stabilize the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0088]

Furthermore, since it has become possible to use the coefficient  $\beta$  shown in the foregoing equation (2) to variably adjust a change in the detection voltage V2 outputted from the detecting unit 7 with respect to a change in the power source voltage Vcc,

it is possible to perform an adjustment to inhibit a change in the DC voltage  $V_4$  and the control current  $I_d$ , corresponding to an actual changing characteristic of the power source voltage  $V_{cc}$ . For this reason, even in a case where the illuminance or the light intensity of the light emission element FL is controlled using various power supplies PWR having different power source voltages  $V_{cc}$  and voltage fluctuations, it is still possible to obtain an advantage of performing an adjustment to inhibit a change of the DC voltage  $V_4$  in response to the characteristic of the power supply PWR.

[Example 1]

[0089]

Next, with reference to Fig. 4, description will be given to explain in more detail an example of the illumination control circuit 1 formed according to the first embodiment of the present invention.

[0090]

Fig. 4 is a circuit diagram showing a structure of the illumination control circuit of the present embodiment, with elements identical or equal to those in Fig. 1 being represented by the same reference numerals.

[0091]

As shown in Fig. 4, similar to the illumination control circuit of the embodiment shown in Fig. 1, this illumination control circuit 1 comprises: a control signal source 2, a switching element 3, a smoothing unit 4, a driving element 5, a reference unit 6, a detecting unit 7, and a compensation unit 8.

[0092]

The control signal source 2 comprises an oscillating circuit

2a outputting PWM signal S0, NPN transistor 2f, and bias resistors 2b-2e. The NPN transistor 2f invert-amplifies the PWM signal S0. The invert-amplified PWM signal S1 is then supplied to the base of the switching element 3.

5 [0093]

The switching element 3 is formed of PNP transistor, its emitter is connected to the plus side output terminal (+) of the power supply PWR through the zener diode 9, while its collector is connected to the smoothing unit 4. Then, by performing a switching operation in accordance with the PWM signal S1 supplied to the base of the PNP transistor, it is possible to output a square wave switching signal S2.

[0094]

The smoothing unit 4 is a  $\pi$  type low pass filter formed of resistors 4a-4d and capacitors 4e, 4f and generates DC voltage V4 by smoothing the switching signal S2.

[0095]

The driving element 5 is formed of PNP transistor 5, its emitter is connected to the plus side output terminal (+) of the power supply PWR through the light emission element FL, while its collector is connected to the compensation unit 8, with the DC voltage V4 applied to the base thereof.

[0096]

The compensation unit 8 is formed of PNP transistor 8 connected between the collector of the PNP transistor 5 and the minus side output terminal (-) of the power supply PWR, with its collector connected to the minus side output terminal (-) and its emitter

connected to the collector of the PNP transistor 5, respectively.  
[0097]

The reference unit 6 is formed of the zener diode 6 for generating the constant voltage  $V_z$ , so as to generate the constant voltage  $V_z$  which is smaller than the power source voltage  $V_{cc}$ .  
[0098]

The detecting unit 7 comprises a plurality of resistors  $R_{11}$ - $R_{13}$ , a changeover switch SW and a resistor R2 connected in series with the zener diode 6 between the plus side output terminal (+) and the minus side output terminal (-) of the power supply PWR. By performing a changeover operation on the changeover switch SW, it is possible to connect any one of the resistors  $R_{11}$  -  $R_{13}$  between the plus side output terminal(+) of the power supply PWR on one hand and the zener diode 6 on the other.  
[0099]

Moreover, with regard to the resistors  $R_{11}$ - $R_{13}$ , the resistor  $R_{11}$  has the smallest resistance, the resistor  $R_{12}$  has a relatively large resistance, and the resistor  $R_{13}$  has the largest resistance. Further, the resistor  $R_{12}$  is formed of a constant resistor having a predetermined resistance value.  
[0100]

Then, once the changeover switch SW is switched over to the resistor  $R_{11}$  side, the resistors  $R_{11}$  and R2 will divide a differential voltage ( $V_{cc}-V_z$ ) of the power source voltage  $V_{cc}$  and the constant voltage  $V_z$ , thereby generating a detection voltage  $V_2$  across the resistor R2 in accordance with a relation expressed by the following equation (3).

[0101]

$$V2 = (V_{cc} - V_z) \times R2 / (R11 + R2) = \alpha1 \times (V_{cc} - V_z) \dots (3)$$

Further, once the changeover switch SW is switched over to the resistor R12 side, the resistors R12 and R2 will divide a differential voltage ( $V_{cc} - V_z$ ) of the power source voltage  $V_{cc}$  and the constant voltage  $V_z$ , thereby generating a detection voltage  $V2$  across the resistor R2 in accordance with a relation expressed by the following equation (4).

[0102]

10 
$$V2 = (V_{cc} - V_z) \times R2 / (R12 + R2) = \alpha2 \times (V_{cc} - V_z) \dots (4)$$

Moreover, once the changeover switch SW is switched over to the resistor R13 side, the resistors R13 and R2 will divide a differential voltage ( $V_{cc} - V_z$ ) of the power source voltage  $V_{cc}$  and the constant voltage  $V_z$ , thereby generating a detection voltage  $V2$  across the resistor R2 in accordance with a relation expressed by the following equation (5).

[0103]

$$V2 = (V_{cc} - V_z) \times R2 / (R13 + R2) = \alpha3 \times (V_{cc} - V_z) \dots (5)$$

However, the coefficients  $\alpha1$ ,  $\alpha2$ , and  $\alpha3$  in the above equations (3), (4), and (5) represent partial voltage ratios based on the resistors R11, R12, and R13 and the constant resistor R2, and are equivalent to the coefficient  $\alpha$  in the above equation (1).

[0104]

The detection voltage  $V2$  generated across the resistor R2 is applied to the base of the PNP transistor 8 forming the compensation unit 8, thereby generating a compensation voltage  $V3$  between the emitter and the collector of the PNP transistor 8.



[0105]

Next, description will be given to explain an operation of the illumination control circuit 1 of the present embodiment, with reference to Fig. 2 and Fig. 4.

5 [0106]

First, description will be given to explain a basic operation of the illumination control circuit 1 of the present embodiment, with reference to Fig. 2(a).

[0107]

10 The zener diode 6 generates the constant voltage  $V_z$ , the detecting unit 7 formed of the resistors  $R_{11}$ - $R_{13}$ , the changeover switch SW and the resistor R2 will divide the foregoing differential voltage ( $V_{cc}-V_z$ ), thereby generating the detection voltage  $V_2$  across the resistor R2. Then, the PNP transistor 8 power-amplifies the  
15 detection voltage  $V_2$ , thereby generating the compensation voltage  $V_3$  which follows the detection voltage  $V_2$ .

[0108]

Namely, as described above with reference to the above-mentioned equations (3), (4), and (5), when the changeover  
20 switch SW is switched to the resistor  $R_{11}$  side, a detection voltage  $V_2$  will be generated in accordance with the foregoing equation (3). When the changeover switch SW is switched to the resistor  $R_{12}$  side, a detection voltage  $V_2$  will be generated in accordance with the foregoing equation (4). When the changeover switch SW is switched  
25 to the resistor  $R_{13}$  side, a detection voltage  $V_2$  will be generated in accordance with the foregoing equation (5). Then, the PNP transistor 8 power-amplifies a detection voltage  $V_2$ , thereby

generating the compensation voltage  $V_3$  which follows each detection voltage  $V_2$ .

[0109]

Furthermore, since the emitter of the PNP transistor 8 and  
5 the collector of the PNP transistor 5 are connected to each other,  
an impedance  $Z_8$  when viewing the emitter of the PNP transistor 8  
from the PNP transistor 5 will be lower than an impedance  $Z_5$  when  
viewing the PNP transistor 5 from the PNP transistor 8. As a result,  
a potential at the junction point P between the PNP transistor 5  
10 and the PNP transistor 8 can be determined by the compensation voltage  
 $V_3$ , and there will be a driving voltage  $V_x$  which is equivalent to  
a difference between the power source voltage  $V_{cc}$  and the compensation  
voltage  $V_3$ , and applied between two ends of the PNP transistor 5  
and the light emission element FL.

15 [0110]

Furthermore, when the power source voltage  $V_{cc}$  is kept constant  
without any change, the detection voltage  $V_2$  and the compensation  
voltage  $V_3$  can also be kept constant, thereby maintaining the driving  
voltage  $V_x$  at the above-mentioned voltage ( $V_{cc}-V_3$ ).

20 [0111]

Under the above-described condition, once a user or the like  
performs an external operation on the oscillating circuit 2a to  
output PWM signal  $S_0$  having an appropriate pulse width  $W$ , the NPN  
transistor 2f will generate PWM signal  $S_1$  formed by invert-amplifying  
25 the PWM signal  $S_0$ , and supply the same to the base of the switching  
element 3. Then, the switching element 3 generates a switching signal  
 $S_2$  according to the PWM signal  $S_1$ , the smoothing unit 4 generates

a DC voltage V4 in accordance with the switching signal S2, and the PNP transistor 5 sets up a predetermined driving electric power in response to the DC voltage V4, thereby adjusting the illuminance or the light intensity (so-called brightness) of the light emission element FL to a desired brightness in response to the pulse width W of the PWM signal S1.

[0112]

Therefore, once a user or the like performs an external operation on the oscillating circuit 2a to properly adjust the pulse width W of the PWM signal S0, it is possible to adjust the illuminance or the light intensity (so-called brightness) of the light emission element FL to a desired brightness.

[0113]

Furthermore, once a user or the like performs an external operation on the oscillating circuit 2a to properly maintain the pulse width W of the PWM signal S0 at an appropriate pulse width, the DC voltage V4 will remain at a voltage in response to its pulse width W, thereby maintaining the light emission element FL at an illuminance or a light intensity (so-called brightness) desired by a user or the like.

[0114]

Furthermore, according to the illumination control unit 1 of the present embodiment, when the power source voltage Vcc has been stabilized at a constant voltage, since the driving voltage Vx is also maintained at a predetermined value, it is possible to avoid a large load on the PNP transistor 5, thereby maintaining the illuminance or the light intensity (so-called brightness) of the

light emission element FL at a user's desired level without any change.

[0115]

Next, description will be given to explain an operation of  
5 the illumination control circuit 1 when the power source voltage  $V_{cc}$  of the power supply PWR has changed due to a fluctuation or the like.

[0116]

When the power source voltage  $V_{cc}$  of the power supply PWR has  
10 gone up due to a fluctuation or the like, a constant voltage  $V_z$  will occur across the zener diode 6 without being affected by any change of the power source voltage  $V_{cc}$ . As a result, as described above with reference to the foregoing equations (3), (4), and (5), when the changeover switch SW is switched to the resistor R11 side,  
15 a detection voltage  $V_2$  will rise in accordance with the foregoing equation (3). When the changeover switch SW is switched to the resistor R12 side, a detection voltage  $V_2$  will rise in accordance with the foregoing equation (4). When the changeover switch SW is switched to the resistor R13 side, a detection voltage  $V_2$  will rise  
20 in accordance with the foregoing equation (5). Then, the PNP transistor 8 power-amplifies a detection voltage  $V_2$ , thereby generating a compensation voltage  $V_3$  which follows each detection voltage  $V_2$ .

[0117]

25 Then, once the power source voltage  $V_{cc}$  goes up under a condition in which any one of the resistors R11, R12, and R13 has been switched so as to be selected by virtue of the changeover switch SW, the

driving voltage  $V_x$  applied between the light emission element FL and the PNP transistor 5 will change with the rising of the compensation voltage  $V_3$ , in a manner as shown in Fig. 2(b).

[0118]

5            Here, since the driving voltage  $V_x$  is a voltage ( $V_{cc}-V_3$ ) formed by deducting the compensation voltage  $V_3$  from the power source voltage  $V_{cc}$ , a rise in the power source voltage  $V_{cc}$  will cause a rise in the compensation voltage  $V_3$ . Therefore, the voltage ( $V_{cc}-V_3$ ), i.e., the driving voltage  $V_x$  will not have a significant change. For this  
10 reason, it is possible to maintain a condition in which there is not a large load exerted on the driving element 5.

[0119]

Under the above-described condition, once a user or the like performs an external operation on the oscillating circuit 2a and  
15 the PWM signal  $S_0$  having an appropriate width  $W$  is outputted and kept at a pulse width  $W$  of an earlier time at which the power source voltage  $V_{cc}$  has not changed, the following operations will occur. Namely, the switching element 3 generates the switching signal  $S_2$  according to the PWM signal  $S_1$  formed by invert-amplifying the PWM  
20 signal  $S_0$ , the smoothing unit 4 generates DC voltage  $V_4$  in accordance with the switching signal  $S_2$ , and the PNP transistor 5 sets up a predetermined driving electric power in response to the DC voltage  $V_4$ , thereby adjusting the illuminance or the light intensity (so-called brightness) of the light emission element FL to a desired  
25 brightness in response to the pulse width  $W$  of the PWM signal  $S_1$ .

[0120]

Namely, even in a case where the power source voltage  $V_{cc}$  has

changed, there would be no significant change in the driving voltage  $V_x$  which is equivalent to a difference between the power source voltage  $V_{cc}$  and the compensation voltage  $V_3$ . As a result, it is possible to cause the light emission element FL to emit a light  
5 at an illuminance or a light intensity (so-called brightness) desired by a user or the like, in response to the pulse width  $W$  of the PWM signal  $S_0$ .

[0121]

As described above, according to the illumination control  
10 circuit 1 of the present embodiment, the light emission element FL and the PNP transistors 5, 8 are connected in series with respect to the power source voltage  $V_{cc}$ , the detecting unit 7 detects a voltage fluctuation of the power source voltage  $V_{cc}$ , while the PNP transistor 8 generates a compensation voltage  $V_3$  which follows a  
15 change of the power source voltage  $V_{cc}$ . As a result, even when there is a change in the power source voltage  $V_{cc}$ , it is still possible to reduce a fluctuation of a voltage, i.e., a driving voltage  $V_x$  between the light emission element FL and the PNP transistor 5, thereby reducing a load on the PNP transistor 5. Further, since  
20 it is possible to reduce an undesired fluctuation in the driving voltage  $V_x$ , it is possible to stabilize the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0122]

Furthermore, the zener diode 6 and the detecting unit 7 are  
25 provided with respect to the power source voltage  $V_{cc}$ , while the detecting unit 7 detects a change in the power source voltage  $V_{cc}$  in accordance with the differential voltage ( $V_{cc}-V_z$ ) between the

power source voltage  $V_{cc}$  and the constant voltage  $V_z$  generated in the zener diode 6, with the PNP transistor 8 generating the compensation voltage  $V_3$  in accordance with the detection result (detection voltage)  $V_2$ . As a result, even when the power source voltage  $V_{cc}$  becomes higher than the so-called rated voltage, it is still possible to reduce a fluctuation of the driving voltage  $V_x$  between two ends of the light emission element FL and the PNP transistor 5, thereby reducing a load on the PNP transistor 5 and stabilizing the illuminance or the light intensity (so-called brightness) of the light emission element FL. Moreover, even when the power source voltage  $V_{cc}$  becomes lower than the so-called rated voltage, within a range from the rated voltage to the constant voltage  $V_z$ , it is still possible to reduce a fluctuation of the driving voltage  $V_x$  between two ends of the light emission element FL and the PNP transistor 5, thereby reducing a load on the PNP transistor 5 and stabilizing the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0123]

Furthermore, since it has become possible to use the changeover switch SW to variably adjust a change of the detection voltage  $V_2$  outputted from the detecting unit 7 with respect to a change of the power source voltage  $V_{cc}$ , it is possible to adjust the driving voltage  $V_x$  with respect to a change of the power source voltage  $V_{cc}$  in a manner shown in Fig. 2(c). For example, it is possible to perform an adjustment to inhibit a fluctuation of the driving voltage  $V_x$ , corresponding to an actual changing characteristic of the power source voltage  $V_{cc}$ .

[0124]

For this reason, even when using various types of power supplies PWR having different power source voltages  $V_{cc}$  and different voltage fluctuations to control the illuminance or the light intensity of the light emission element FL, it is still possible to perform an adjustment to inhibit a fluctuation of the driving voltage  $V_x$  in accordance with a characteristic of the power supply PWR.

[0125]

Next, description will be given to explain in more detail an example of an illumination control circuit according to a second embodiment of the present invention, with reference to Fig. 5.

[0126]

Fig. 5 is a circuit diagram showing a structure of the illumination control circuit of the present embodiment, with elements identical or equal to those in Fig. 3 being represented by the same reference numerals.

[0127]

As shown in Fig. 5, similar to the illumination control circuit of the embodiment shown in Fig. 3, this illumination control circuit 1 comprises: a control signal source 2, a switching element 3, a smoothing unit 4, a driving element 5, a reference unit 6, a detecting unit 7, and a compensation unit 10.

[0128]

The control signal source 2 comprises an oscillating circuit 2a which outputs the PWM signal S0, as well as resistors 2b, 2c for biasing the switching element 3, and divides the PWM signal S0 outputted from the oscillating circuit 2a into PWM signal S1



by virtue of the resistors 2b, 2c and supplies the same to the base of the switching element 3.

[0129]

The switching element 3 is formed of PNP transistor, its emitter is connected to the plus side output terminal (+) of the power supply PWR, while its collector is connected to the smoothing unit 4. Then, by performing a switching operation in accordance with the PWM signal S1 supplied to the base of the PNP transistor, it is possible to output a square wave switching signal S2.

10 [0130]

The smoothing unit 4 is a  $\pi$  type low pass filter formed of resistors 4g-4h and an NPN transistor Tr1. Resistors 4g-4h and capacitors 4i, 4j generate a DC voltage V4a by smoothing the switching signal S2, while the NPN transistor Tr1 power-amplifies the DC-voltage V4a so as to generate a DC voltage V4 corresponding to the DC-voltage V4a in the emitter thereof.

[0131]

The compensation unit 10 is formed of a differential amplifier circuit including NPN transistors Tr2, Tr3 and bias resistors r1-r4, while the NPN transistor Tr2 connected to the driving element 5 generates the control current Id in response to the DC voltage V4.

[0132]

The driving element 5 is formed of the PNP transistor 5, its emitter is connected to the plus side output terminal (+) of the power supply PWR, its collector is connected to the minus side output terminal (-) of the power supply PWR through the light emission element FL, and its base is connected to the collector of the NPN

transistor Tr2, thereby making it possible to perform an operation in accordance with the control current Id.

[0133]

The reference unit 6 is formed of the zener diode 6 which generates the constant voltage Vz, as well as another constant voltage Vz which is smaller than the power source voltage Vcc.

[0134]

The detecting unit 7 includes the zener diode 6 and the resistors R1, R2 connected in series between the plus side output terminal (+) and the minus side output terminal (-) of the power supply PWR. As shown in the diagram, the emitter of the switching element 3 consisting of PNP transistor as well as the resistor R2 are connected at a junction point between the resistors R1, R2.

[0135]

The resistors R1 and R2, by dividing the differential voltage (Vcc-Vz) of the power source voltage Vcc and the constant voltage Vz, can generate a detection voltage V2 in accordance with the following equation (6).

[0136]

$$\begin{aligned} V2 &= (V_{cc} - V_z) \times R1 / (R1 + R2) + V_z \\ &= \beta \times (V_{cc} - V_z) + V_z \quad \dots (6) \end{aligned}$$

Next, description will be given to explain an operation of the illumination control circuit 1 formed according to the present embodiment.

[0137]

Next, description will be given to explain an operation of the illumination control circuit 1 having the above-described

structure.

[0138]

At first, description will be given to explain an operation of the illumination control circuit 1 in a case where the power source voltage  $V_{cc}$  remains constant without any change.

[0139]

Namely, the reference unit 6 generates the constant voltage  $V_z$ , while the above-mentioned detecting unit 7 sets, in accordance with the differential voltage ( $V_{cc}-V_z$ ) and by virtue of the generated detection voltage  $V_2$ , an emitter potential of the switching element 3 consisting of the PNP transistor. Furthermore, in a case where the power source voltage  $V_{cc}$  remains constant without any change, the detection voltage  $V_2$  will become a constant voltage, so that an emitter potential of the switching element 3 consisting of the PNP transistor can be maintained at a constant voltage by virtue of the detection voltage  $V_2$ .

[0140]

In this state, once a user or the like performs an external operation on the oscillating circuit 2a to output the PWM signal  $S_0$  having an appropriate pulse width  $W$ , the switching element 3 will generate a switching signal  $S_2$  in accordance with the PWM signal  $S_1$ , while the smoothing unit 4 will generate a DC voltage  $V_4$  in accordance with the switching signal  $S_2$ .

[0141]

When the NPN transistor  $Tr_2$  of the compensation unit 10 generates the control current  $I_d$  in response to the DC voltage  $V_4$  and controls the operation of the PNP transistor 5, the illuminance

or the light intensity (so-called brightness) of the light emission element FL can be adjusted to a brightness in response to the pulse width W of the PWM signal S0.

[0142]

5           Therefore, once a user or the like performs an external operation on the oscillating circuit 2a to adjust the pulse width W of the PWM signal S0 in order to lower the DC voltage V4, the power amplification of the PNP transistor 5 will decline and it is possible to reduce the illuminance or the light intensity  
10 (so-called brightness) of the light emission element FL. On the other hand, upon adjusting the pulse width W of the PWM signal S0 to increase the DC voltage V4, the power amplification of the PNP transistor 5 will increase, thus making it possible to increase the illuminance or the light intensity (so-called brightness) of  
15 the light emission element FL.

[0143]

Moreover, once a user or the like performs an external operation on the oscillating circuit 2a to maintain the pulse width W of the PWM signal S0 at an appropriate pulse width, the DC voltage V4 will  
20 remain at a voltage in response to the pulse width, thereby making it possible to maintain the illuminance or the light intensity (so-called brightness) of the light emission element FL at a desired brightness.

[0144]

25           Next, description will be given to explain an operation of the illumination control circuit 1 in a case where there has been a change in the power source voltage Vcc due to a fluctuation or

the like.

[0145]

In a case where there has been an increase in the power source voltage  $V_{cc}$  of the power supply PWR due to a fluctuation or the like, the zener diode 6 will generate the constant voltage  $V_z$  irrespective of a change in the power source voltage  $V_{cc}$ . Further, in accordance with the above equation (6), the above-mentioned resistors  $R_1$  and  $R_2$  will generate the detection voltage  $V_2$  from the foregoing differential voltage  $(V_{cc}-V_z)$ .

10 [0146]

Here, since a change in the power source voltage  $V_{cc}$  does not cause a change in the constant voltage  $V_z$ , the differential voltage  $(V_{cc}-V_z)$  will rise with an increase in the power source voltage  $V_{cc}$ , while the resistors  $R_1$  and  $R_2$  will detect an increase in the differential voltage  $(V_{cc}-V_z)$ , thereby outputting a detection voltage  $V_2$  which rises following an increase in the power source voltage  $V_{cc}$ , in accordance with the above equation (6).

[0147]

In this way, if the detection voltage  $V_2$  rises with an increase in the power source voltage  $V_{cc}$ , a voltage between the emitter and the base of the switching element 3 consisting of PNP transistor will become large, thereby increasing a voltage amplification factor of the switching element 3.

[0148]

25 Then, once there is an increase in the voltage amplification factor of the switching element 3, an amplitude of the switching signal  $S_2$  will become large, a voltage level of the DC voltage  $V_4$

outputted from the smoothing unit 4 will increase, and there will be an increase in the power amplification of the driving element 5 consisting of PNP transistor, thereby increasing a driving electric power to be supplied to the light emission element FL.

5 [0149]

Here, an important point is that when there is an increase in the power source voltage  $V_{cc}$  due to a fluctuation or the like, the detection voltage  $V_2$  will rise depending on the coefficient  $\beta$  of the above equation (6). As a result, the voltage changing rate of the detection voltage  $V_2$  becomes gentler (smaller) than the voltage changing rate of the power source voltage  $V_{cc}$ . In this way, although a voltage between the emitter and the base of the switching element 3 becomes large with an increase in the power source voltage  $V_{cc}$ , it becomes large at a voltage changing rate which is smaller than the voltage changing rate of the power source voltage  $V_{cc}$ , i.e., becomes large under a condition in which the voltage amplification factor of the switching element 3 has been controlled.

[0150]

Therefore, the amplitude of the switching signal  $S_2$  becomes large in accordance with the voltage amplification factor of the controlled switching element 3, and the voltage level of the DC voltage  $V_4$  outputted from the smoothing unit 4 also goes up according to the voltage amplification factor of the controlled switching element 3. Further, the power amplification of the PNP transistor 5 will also increase in accordance with the voltage amplification factor of the controlled switching element 3, while the driving electric power supplied to the light emission element FL will not

have a significant change.

[0151]

For this reason, there will not be any significant change in the illuminance or the light intensity (so-called brightness) of the light emission element FL. Even if a change occurs, such a change will be controlled within a range which does not involve a brightness irregularity.

[0152]

Moreover, even in a case where the power source voltage  $V_{cc}$  has dropped, if the power source voltage  $V_{cc}$  drops from a rated voltage into a range where the reference unit 6 generates the constant voltage  $V_z$ , it is possible ensure, by virtue of the detection voltage  $V_2$ , a bias voltage between the emitter and the base of the switching element 3 consisting of the PNP transistor. Besides, the detection voltage  $V_2$  will drop depending on the coefficient  $\beta$  of the above equation (6). As a result, the voltage changing rate of the detection voltage  $V_2$  will become gentler (smaller) than the voltage changing rate of the power source voltage  $V_{cc}$ .

[0153]

In this way, even though a voltage between the emitter and the base of the switching element 3 decreases with a decrease of the power source voltage  $V_{cc}$ , such a decrease will happen at a voltage changing rate which is smaller than the voltage changing rate of the power source voltage  $V_{cc}$ , the voltage amplification factor of the switching element 3 will become small in a controlled state, the power amplification of the PNP transistor 5 will also decrease according to the voltage amplification factor of the controlled

switching element 3, with no significant change in the driving electric power supplied to the light emission element FL. For this reason, even if the power source voltage Vcc has dropped, there would be no significant change in the illuminance or the light intensity (so-called brightness) of the light emission element FL, thereby ensuring an effect that any change remains within a range not involving a brightness irregularity.

[0154]

As described above, according to the illumination control circuit 1 of the present embodiment, even if there has been a fluctuation or the like in the power source voltage Vcc, it is still possible to adjust the DC voltage V4 to avoid an increased load on the PNP transistor 5 by virtue of the zener diode 6 and resistors R1, R2, thereby stabilizing the illuminance or the light intensity (so-called brightness) of the light emission element FL.

[0155]

Moreover, since a change in the power source voltage Vcc will soon cause a change in the detection voltage V2, the voltage amplification factor of the switching element 3 will change and the DC voltage V4 will also change. As a result, if explained more exactly, although there will be a change in the illuminance or the light intensity (so-called brightness) of the light emission element FL, it is still possible to reduce a voltage changing rate with respect to the power source voltage Vcc of the detection voltage V2 by adjusting in advance the coefficient  $\beta$  of the detecting unit 7. Further, it is possible to reduce a fluctuation of the DC voltage V4 in a manner such that the illuminance or the light intensity



(so-called brightness) of the light emission element FL changes only within a range which will not be felt by man's eyes. Furthermore, since it is possible to reduce the fluctuation of the DC voltage V4, it is possible to stabilize the illuminance or the light intensity

5 (so-called brightness) of the light emission element FL.

[0156]

Furthermore, since it has been possible to variably adjust, by virtue of the coefficient  $\beta$  of the above equation (6), a change of the detection voltage V2 with respect to the power source voltage Vcc, it is possible to perform an adjustment to inhibit a fluctuation of the DC voltage V4, corresponding to an actual changing characteristic of the power source voltage Vcc. In this way, even in a case where various power supplies PWR having different power source voltages Vcc and different voltage fluctuations are used  
10 to control the illuminance or the light intensity of the light emission element FL, it is still possible to obtain an advantage of performing an adjustment to inhibit a fluctuation of the DC voltage V4, in response to the characteristic of the power supply PWR.  
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